

April 14, 2006
Arc Flash Incident
Building 1006A
Brookhaven National Laboratory

Type B Accident Investigation

Judgment of Needs

J. Sandberg

C-AD

Topics

- Brief Description of the Accident
- The Investigating Boards Conclusion on the Technical Causes of Accident
- Brief Explanation of Technical Issues required to understand the Judgment of Needs (JONs)
- Discussion Technical of JONs and Actions Taken

STAR Detector Power Supply

The Star Detector is powered by Five independent Power Supplies:

The Main solenoid power supply (825 V, 5300 amps)

Two Pole tip trim power supplies (140 V, 1600 amps ea)

Two Space trim power supplies (50 V, 600 amps ea)



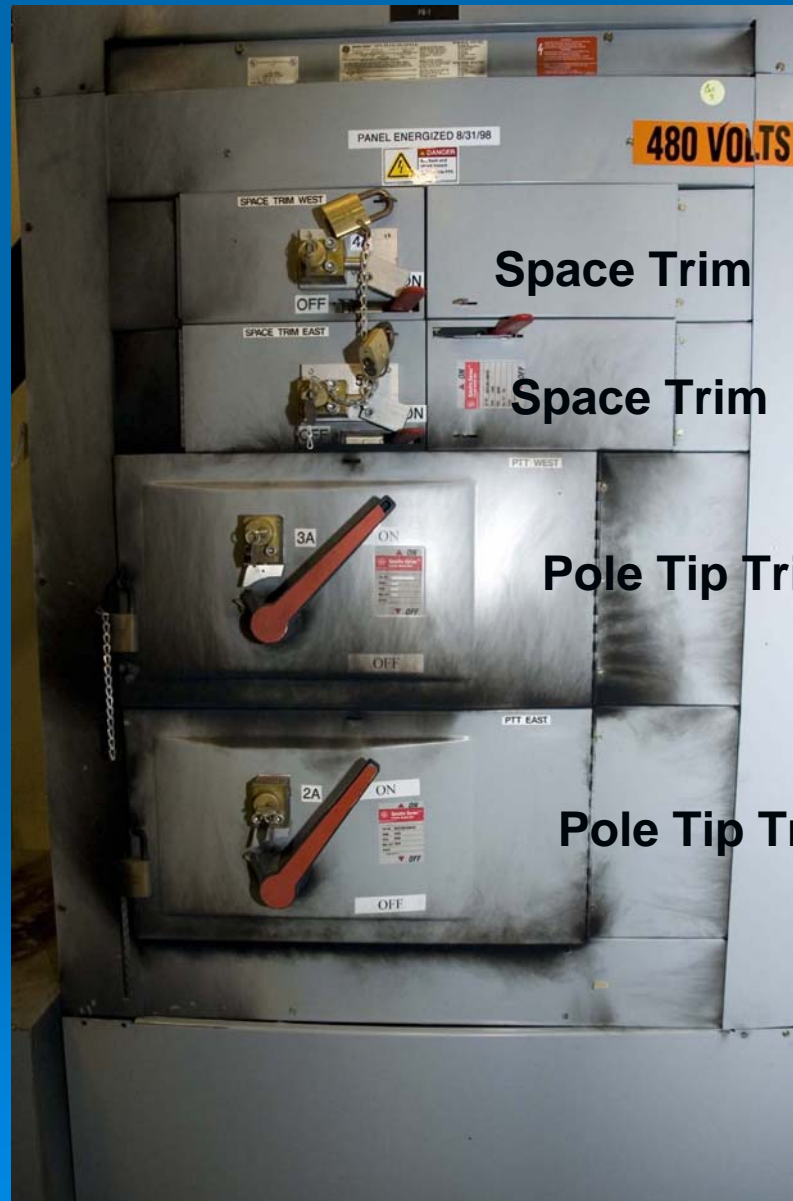
Accident

- April 14, 2006 at ~1020
- Building 1006A Mechanical Loft
- Engineer operates 480 V 400 amp disconnect switch
- Arc flash injuries:
 - 1st degree burns to head, face, chest, and hands
 - 1st and 2nd degree burns to forearms
- Switch panel destroyed

Accident



Accident



Space Trim

Space Trim

Pole Tip Trim West

Pole Tip Trim East

Accident



480 Volt STAR Power Supply Circuit Breaker

C-AD



Injured Engineer's Cotton Short Sleeve Shirt and Cotton Undershirt



Conclusions of Investigation Board

- The direct cause of the accident was an over voltage on the ungrounded delta power system. An arcing ground fault on a feeder cable, occurring at the resonant frequency of the system, caused the over voltage.
- The possibility of failure of the internal structure of the switch could not be ruled out as a contributing cause.

Possible Causes for Arc Flash

➤ High transient voltage

- Ferroresonance on an ungrounded delta system
- Arcing ground fault on ungrounded delta system

➤ Switch Failure



Possible Causes for Arc Flash

➤ Ungrounded Distribution System

No Intentional Grounds Exist

➤ High Resistance grounded System

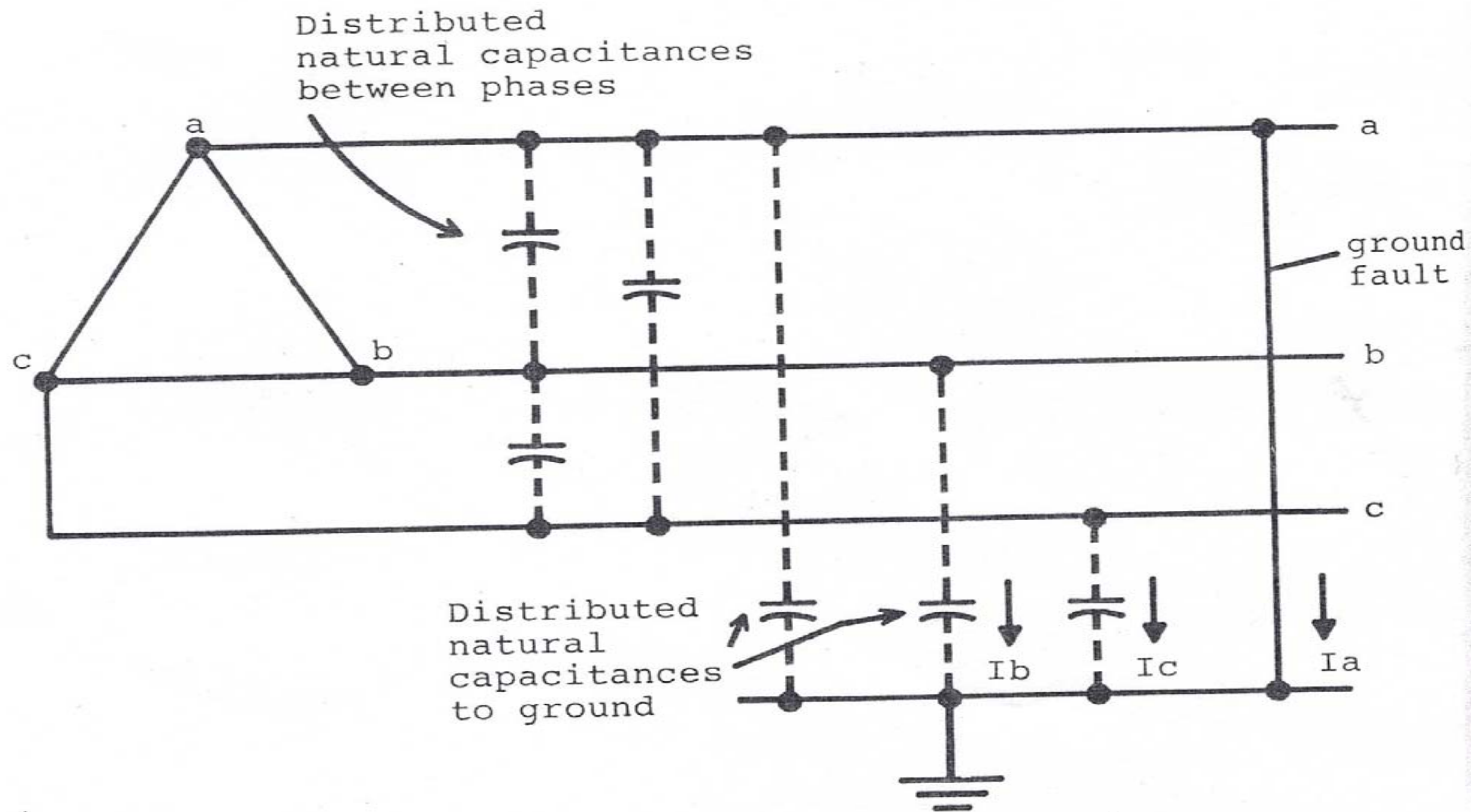
During a (SLG) fault the fault current is limited to less than 10 amperes and greater than the line charging current

➤ Solidly Grounded Neutral

Extremely High (SLG) Fault Currents

Possible Causes for Arc Flash

➤ Ungrounded 480 Volt Distribution System



Possible Causes for Arc Flash


➤ Why not an Ungrounded Distribution System

- Although fault currents are typically lower the line voltages are not solidly referred to ground and they may float up during a fault
- During a SLG fault the two lines would typically rise to 480 volts to ground verses 277 volts to ground
- During some transient conditions such as an arching ground the voltage can rise up to 8 times rated

Possible Causes for Arc Flash

➤ Ferroresonance

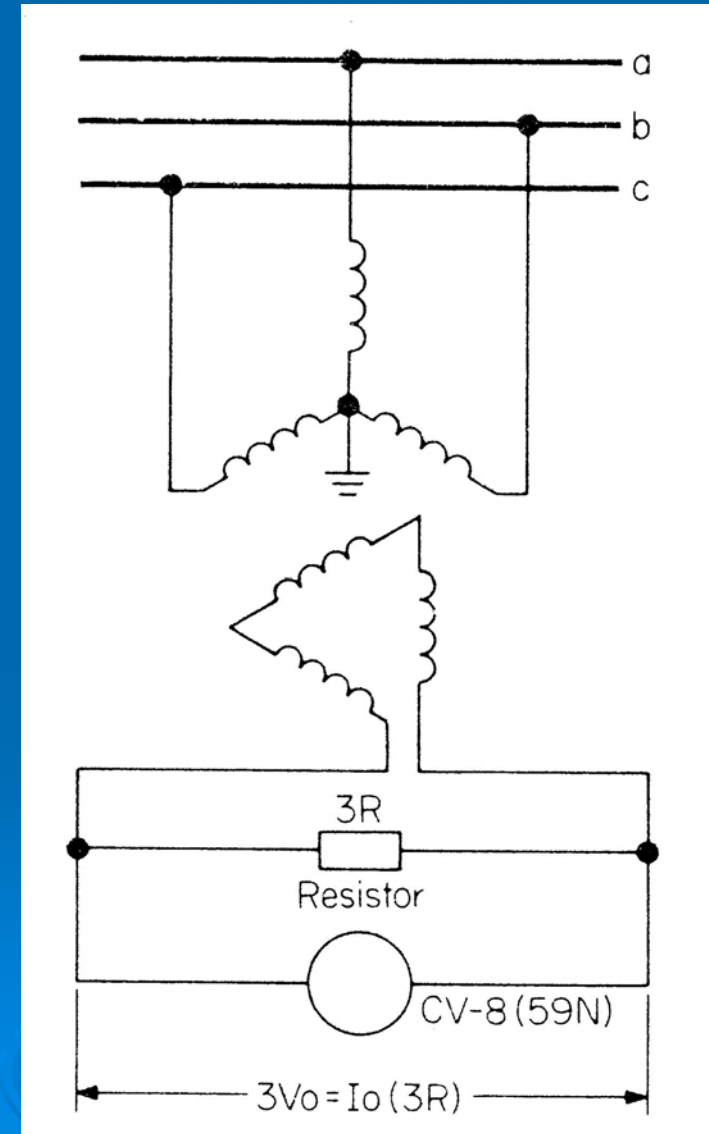
A series resonant circuit can exist between the inductance of a potential transformer and the line capacitance. If the voltage increases on the transformer its iron core can become saturated and its inductance can change quickly. Several resonant frequency can exist and the system can be very hard to analyze.

The background of the slide features several faint, concentric circles in a lighter shade of blue, resembling ripples in water, located in the bottom right and bottom center areas.

Possible Causes for Arc Flash

➤ Ferroresonance

Adding a damping resistor across the broken Delta on a Grounded Wye/ Broken Delta Potential Transformer will Dampen Ferroresonance



An Arcing Ground Fault

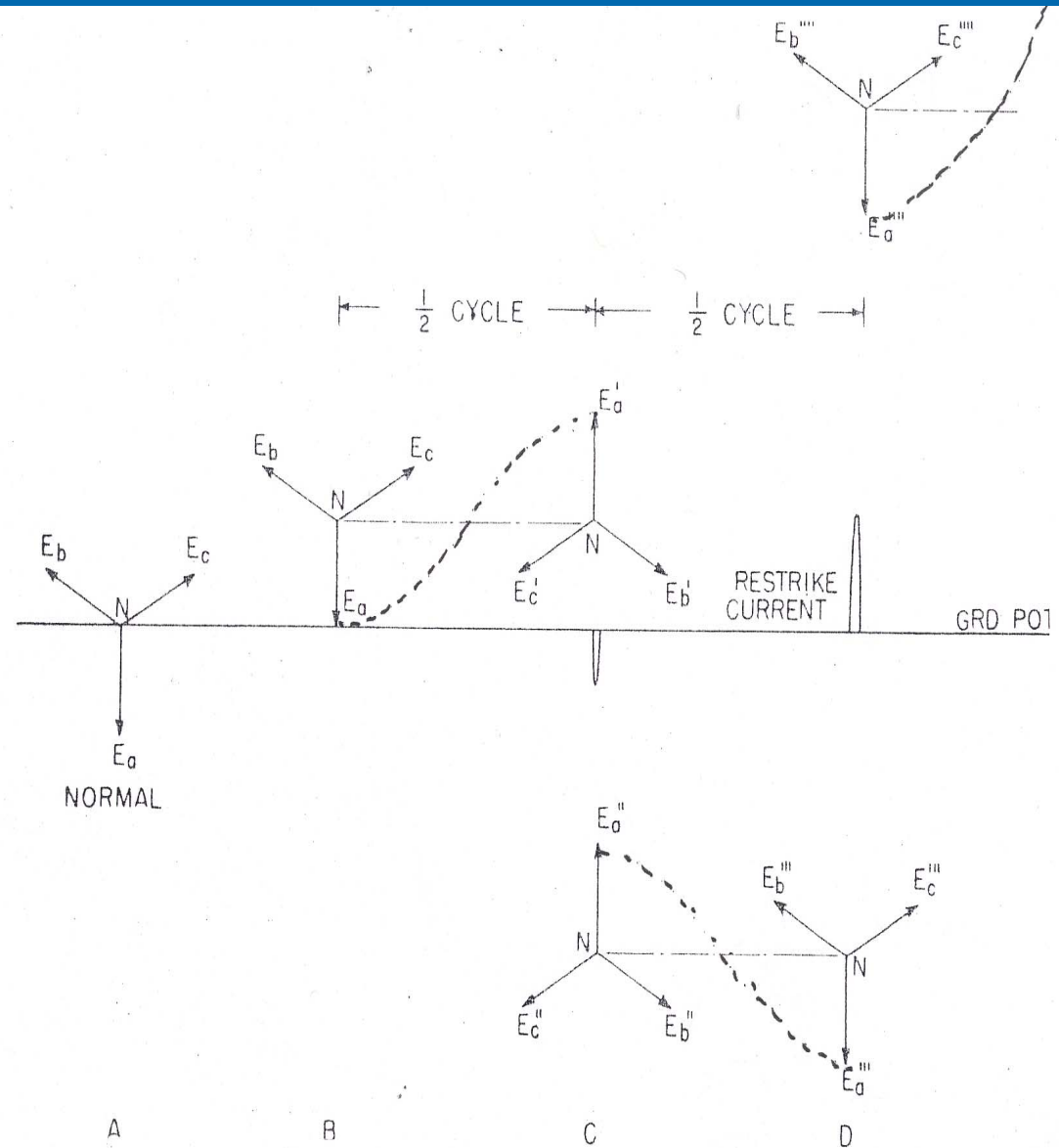


FIG. 5.7 Overvoltages on ungrounded systems due to repetitive momentary contact between one line and ground.

This is shown at *B* in Fig. 5.12. Two things can happen. Either this oscillation will persist to a point where the 60-Hz current from the source is well

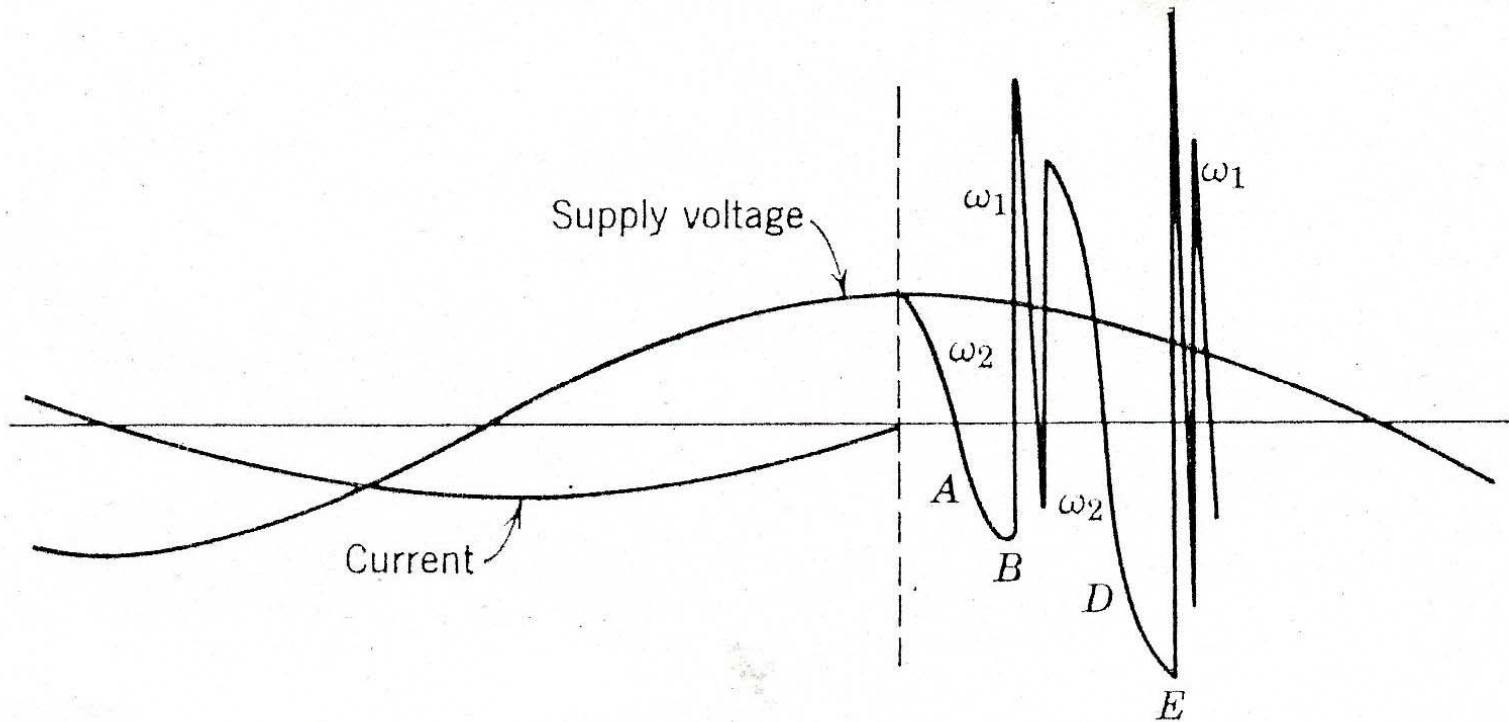


Fig. 5.12. Recurrent restriking phenomenon involving the repetitive restriking and clearing of a switch supplying an oscillatory load.

Accident

- Damaged phase C supply cable



Fuse Disconnect Switch Post Mortem-5/12/06

- Arc between bus bar phase “B” to ground

Arc to ground

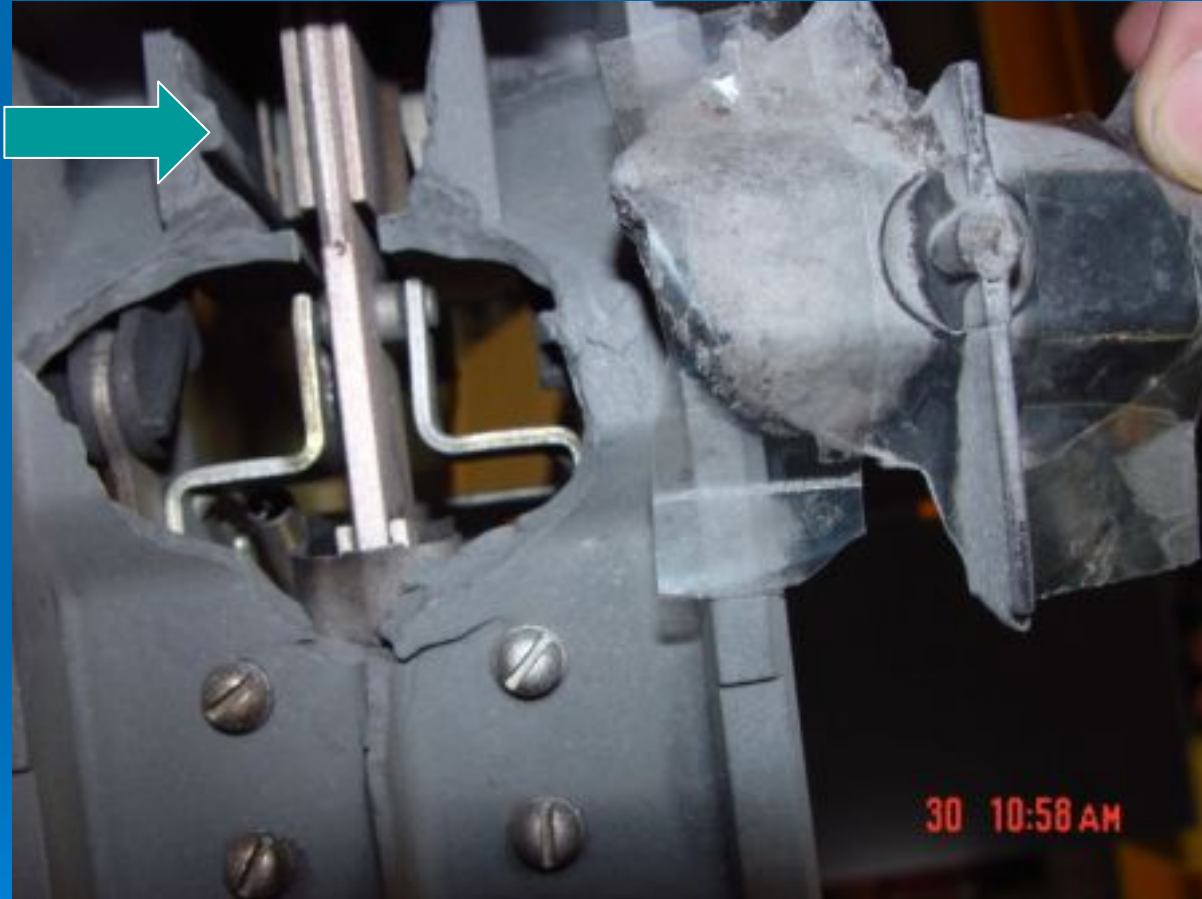


Arc to bus



Possible Switch Failure

Spring Clip should
be here



Broken backing-missing spring clip-Failed unit

Fuse Disconnect Switch Post Mortem-5/1/06



Cracks in Plastic backing after 200 operations-Back
(Reference unit)



Similar crack in failed unit

Fuse Disconnect Switch Post Mortem-5/12/06

Steel Spring Clip



Spring Clip should be here



Damaged unit and a spring clip-bus bar is removed-this damage was hidden with bus in place

What's Next?



JON 1

- Breaker Trip Settings
- Dampening Resistors
- Sensitivity of Ground Fault Relays
 - Surge Suppressors
 - Ungrounded System

- Remote Monitoring of Ground Fault Relays

1002AGFMOD	RHIC SUB 2A	RHIC SUB 2B						
4:04:40 PM 9/26/2006	No Fault	No Fault						
	No Errors	No Errors						
1004AGFMOD	RHIC SUB 4A							
4:04:40 PM 9/26/2006	No Fault							
	No Errors							
1004BGFMOD	RHIC SUB 4B	RHIC SUB 4C						
4:04:40 PM 9/26/2006	No Fault	No Fault						
	No Errors	No Errors						
1006BGFMOD	RHIC SUB 6A							
4:04:40 PM 9/26/2006	No Fault							
	No Errors							
1008AGFMOD	RHIC SUB 8A	RHIC SUB 8B						
4:04:40 PM 9/26/2006	No Fault	No Fault						
	No Errors	No Errors						
1010AGFMOD	RHIC SUB 10A							
4:04:40 PM 9/26/2006	No Fault							
	No Errors							
1012AGFMOD	RHIC SUB 12A							
4:04:40 PM 9/26/2006	No Fault							
	No Errors							
912TDGFMOD	AGS SUB 1F	AGS SUB 1SB	AGS SUB 2F	AGS SUB 2SB	AGS SUB 3F	AGS SUB 3J	AGS SUB E	AGS SUB G
4:04:40 PM 9/26/2006	No Fault	No Fault	No Fault	No Fault	No Fault	No Fault	No Fault	No Fault
	No Errors	No Errors	No Errors	No Errors	No Errors	No Errors	No Errors	No Errors
912TDGFMOD	AGS SUB 1M	AGS SUB 1N	AGS SUB 1P	AGS SUB 2M	AGS SUB 2P	AGS SUB 3M	AGS SUB 5M	AGS SUB 6M
4:04:40 PM 9/26/2006	No Fault	No Fault	No Fault	No Fault	No Fault	No Fault	No Fault	No Fault
	No Errors	No Errors	No Errors	No Errors	No Errors	No Errors	No Errors	No Errors
912TDGFMOD	AGS SUB 1K	AGS SUB 2K	AGS SUB 3K	AGS SUB 4N	AGS SUB 5N	AGS SUB Qvld		
4:04:40 PM 9/26/2006	No Fault	No Fault	No Fault	No Fault	No Fault	No Fault		
	No Errors	No Errors	No Errors	No Errors	No Errors	No Errors		
1006C	Pump Room	STAR MMPS						
4:04:40 PM 9/26/2006	No Fault	No Fault						
	No Errors	No Errors						
test device 2	test 2							
4:04:40 PM 9/26/2006	No Fault							
	No Errors							

JON 3-7

- Why was Remote Ground Fault Monitoring not implemented?

The RHIC SAD states that Remote Ground Fault Monitoring will be Implemented.

This was not Picked up in any of the Reviews



JON 8-9

•What Actions Should be taken if a Ground Fault is detected

Draft

2.21 Modification of Nationally Recognized Test Laboratory Listed Equipment

1. Procedure

This procedure provides instructions to C-A personnel for modifying National Recognized Test Laboratory (NRTL) listed equipment for use at the C-AD.

2. Responsibility

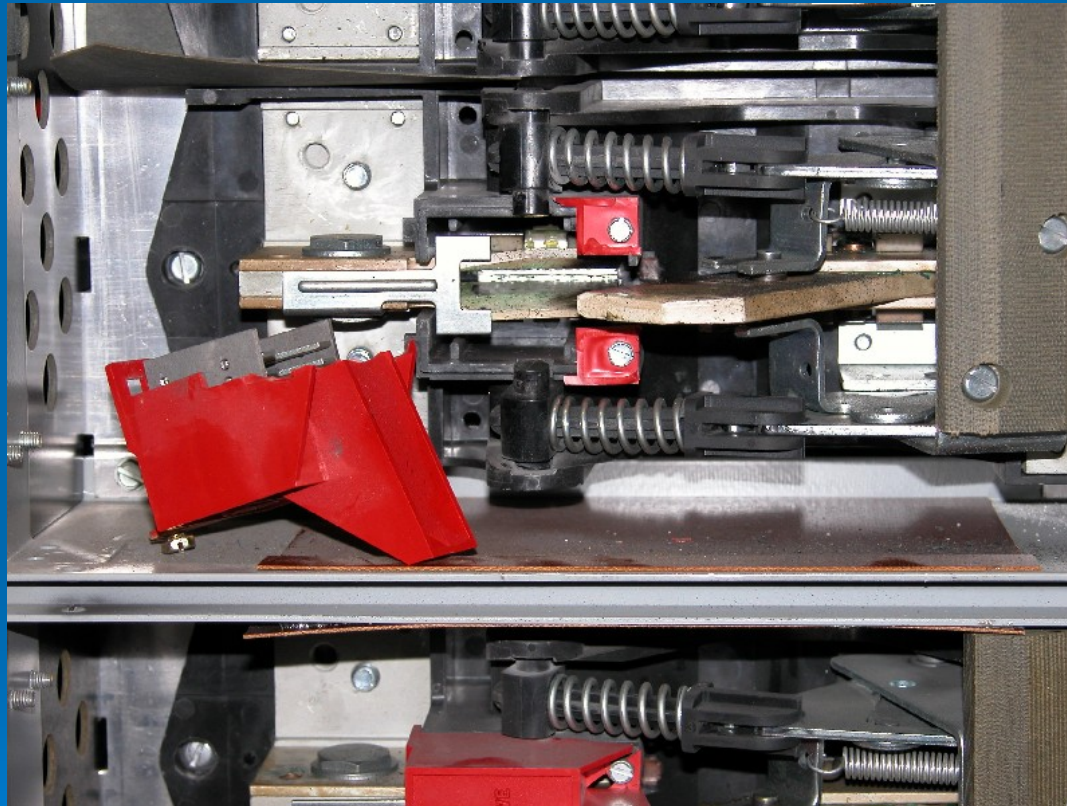
- 2.1 Modifying equipment which is listed by a NRTL may invalidate the listing. It is the responsibility of all C-AD personnel who modify NRTL listed equipment to obtain permission from either the C-AD Chief Mechanical or Chief Electrical Engineer before such modifications are performed.
- 2.2 It is the responsibility of the person or group making the modification to obtain engineering documentation or calculations to verify that making the proposed modification does not compromise the safety aspects of the equipment. If necessary a request may be made to either the Chief Mechanical or Chief Electrical engineer to request that such calculations be performed.

JON 10

- Inspect GE Spectra Series Switches



Broken arc chute in Bldg 902 switch



JON 11

- Set Up a PM Program

Thorough Inspection of all FDS
every Three Years?



JON 12

- Formalized Incident Energy Calculations

During the Summer Shutdown the system configuration has been verified and Arc Flash Calculations are ongoing.

A consultant has been hired by the Laboratory to assist in these calculation

JON 17

Modification of NRTL Equipment



JON 17

Modification of NRTL Equipment

Draft

2.21 Modification of Nationally Recognized Test Laboratory Listed Equipment

1. Procedure

This procedure provides instructions to C-A personnel for modifying National Recognized Test Laboratory (NRTL) listed equipment for use at the C-AD.

2. Responsibility

- 2.1 Modifying equipment which is listed by a NRTL may invalidate the listing. It is the responsibility of all C-AD personnel who modify NRTL listed equipment to obtain permission from either the C-AD Chief Mechanical or Chief Electrical Engineer before such modifications are performed.
- 2.2 It is the responsibility of the person or group making the modification to obtain engineering documentation or calculations to verify that making the proposed modification does not compromise the safety aspects of the equipment. If necessary a request may be made to either the Chief Mechanical or Chief Electrical engineer to request that such calculations be performed.

